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Description

Circuit for a motor vehicle electrical distribution system and an associated operating method

The invention relates to an electrical circuit for a motor vehicle electrical distribution system according to the preamble of claim 1 and to an associated operating method according to the preamble of claim 10.

Multi-voltage motor vehicle electrical distribution systems are known which, for example, have operating voltages of 12 volts and 42 volts and are supplied with electrical energy by an integrated starter generator (ISG).

A double-layer capacitor can, as is known, therein be used as an electrical energy store, with the energy stored in said double-layer capacitor also enabling reliable starting of the internal combustion engine after the vehicle has been temporarily idle.

For example, an engine starting system for a motor vehicle is known (DE 196 01 241 A1) in which system a double-layer capacitor is connected in parallel with a lead-acid battery. Said double-layer capacitor is charged by said lead-acid battery and discharges itself when the engine starts. The load on the lead-acid battery when the engine starts is in this way reduced.

Since, however, commercially available double-layer capacitors exhibit relatively substantial self-discharging, to enable reliable starting of the internal combustion engine the double-layer capacitor will have to be recharged from the vehicle battery at intervals of several days when

the vehicle has been idle for longer periods.

The double-layer capacitor is here recharged, for example, via a dc-dc converter from the 12V vehicle battery; this, however, entails various disadvantages.

On the one hand the dc-dc converter is as a rule designed for electrical loads rated between 1 and 3 kW, so that substantial electrical losses will occur when the double-layer capacitor is recharged while the vehicle is idle.

On the other hand, as well as the double-layer capacitor it is also necessary here to charge the dc link capacitor whose function, with its large capacitance of several tens of thousands of μF, is to smooth the ripple occurring when the three-phase alternating current generated in the ISG is being rectified. The additionally required charging of the dc link capacitor likewise increases energy consumption when the vehicle is idle. This is particularly serious because, owing to its large capacitance, the dc link capacitor exhibits a high degree of self-discharging due to its physical design, and that necessitates frequent recharging.

Finally, the known type of recharging requires a switching operation, which results in further losses due in the case of electro-mechanical relays to the excitation current and in the case of power semiconductors to the control current.

The object of the invention is thus to recharge a capacitor stack - referred to below also as a double-layer capacitor - in a motor vehicle-vehicle electrical distribution system with minimal loss of energy while the vehicle is idle.

Said object is achieved, proceeding from a known circuit

according to the preamble of claim 1, by means of the characterizing features of claim 1 and - in terms of a corresponding operating method - by means of the features of claim 10.

The invention includes the general technical theory of charging the double-layer capacitor by means of the charge-equalizing circuit present in any event.

The invention is not, though, restricted to the recharging of double-layer capacitors. Rather it is also conceivable to employ, instead of double-layer capacitors, other types of energy stores having a plurality of storage elements. Only the term 'double-layer capacitor' is, however, used on many occasions below for simplicity, despite its being possible to use other types of electrical energy stores instead.

Charge-equalizing circuits of the above-mentioned kind are known per se and are described in, for example, EP 0 432 639 A2, so that the content of said publication is to be included in the present description. The invention is not, however, restricted to the types of charge-equalizing circuits described therein but can also be implemented using other types of charge-equalizing circuits.

The charge-equalizing circuit is customarily connected in parallel with the double-layer capacitor, with said double-layer capacitor comprising a plurality of capacitors connected in series. The charge-equalizing circuit is therefore then powered by the double-layer capacitor itself, so that only charge equalizing between the individual capacitors of the double-layer capacitor is possible whereas charging of the double-layer capacitor as a whole is not possible.

However, in a preferred embodiment of the invention the charge-equalizing circuit optionally enables charge equalizing between the individual capacitors of the double-layer capacitor or charging of the double-layer capacitor as a whole. The charge-equalizing circuit is for this purpose connected by means of a first switching element to a first power supply and by means of a second switching element to the energy store. Either charge equalizing or charging of the double-layer capacitor will then take place depending on the switching status of said two switching elements.

When the second switching element is closed while the first switching element is open, the charge-equalizing circuit will be connected to the double-layer capacitor and split from the first power supply, with the charge-equalizing circuit being supplied with current from the first power supply. In this case the charge-equalizing circuit will only enable charge equalizing between the individual capacitors of the double-layer capacitor but no charging of the double-layer capacitor as a whole.

For charging the double-layer capacitor the second switching element is, by contrast, opened and the first switching element closed, so that the charge-equalizing circuit is electrically split from the double-layer capacitor and connected to the first power supply. In this case the charge-equalizing circuit will therefore no longer be powered by the double-layer capacitor so that recharging of the double-layer capacitor as a whole is possible. Charge equalizing between the individual capacitors of the double-layer capacitor will, however, here take place additionally.

In an advantageous variant of the invention the double-layer

capacitor can optionally be charged from the first power supply or from an additional second power supply. This is advantageous in, for example, multi-voltage electrical distribution systems of motor vehicles having, for instance, a 12V battery and additionally a 36V battery for a 42V vehicle electrical distribution system. The double-layer capacitor can then be recharged by the battery having the better charging level. The charge-equalizing circuit is in this variant of the invention therefore connected by means of the first switching element to the first power supply (the 12V battery, for instance) and additionally by means of a third switching element to a second power supply (the 36V battery, for instance). In order to charge the double-layer capacitor from the first power supply, the first switching element is closed while the third switching element is open. To charge the double-layer capacitor from the second power supply the third switching element is, by contrast, closed while the first switching element is open.

The above explanations alone suffice to show that the term 'power supply' as employed within the scope of the invention is not restricted to the lead-acid batteries customary in motor vehicles but also includes other types of rechargeable batteries.

The individual switching elements are preferably driven by means of a control unit preferably connected to a timer for the purpose of checking the double-layer capacitor at regular intervals and, when necessary, recharging it.

Said control unit preferably has a first comparator unit that compares the double-layer capacitor's charge level with a first minimum value in order to recharge said double-layer capacitor if its charge level falls below the first minimum

value. Said first comparator unit preferably additionally compares the energy store's charge level during recharging with a first maximum value in order to avoid excessive recharging of the double-layer capacitor.

The double-layer capacitor will preferably only be recharged if the first power supply (12V battery, for instance) or the second power supply (36V battery, for instance) has been sufficiently charged.

In a preferred embodiment a second comparator unit is therefore provided which measures the charging level of the first power supply and drives the first switching element as a function of the charging level measured. The first switching element will preferably only be switched through if the charging level of the first power supply is sufficient to enable recharging of the double-layer capacitor.

A third comparator unit is preferably additionally provided that measures the charging level of the second power supply (36V battery, for instance) and drives the third switching element as a function of the charging level measured, with the first switching element preferably only being switched through if the charging level of the second power supply is sufficient to enable recharging of the double-layer capacitor.

Relays, for instance, or semiconductor switches can be employed within the scope of the invention as switching elements. What are termed transfer gates are, however, preferably used as switching elements because the polarity of the differential voltage between the double-layer capacitor and the first power supply (12V battery, for

instance) or, as the case may be, second power supply (36V battery, for instance) can be of either kind. Transfer gates of this kind are known per se and consist of two series-connected transistors preferably embodied as MOSFETs.

The invention furthermore includes a corresponding operating method for an electrical circuit of this type.

Other advantageous developments of the invention are contained in the dependent claims or will be explained below, together with the description of the preferred exemplary embodiment of the invention, with reference to the drawings, in which:

Figure 1 shows a circuit according to the invention for a motor vehicle electrical distribution system,

Figure 2 shows a control unit for the circuit shown in Figure 1,

Figure 3 shows the operating method of the circuit shown in Figure 1, and

Figure 4 shows a preferred exemplary embodiment of the switching elements in the case of the circuit shown in Figure 1.

Figure 1 is a simplified diagram of a multi-voltage vehicle electrical distribution system of a vehicle having two system voltages of 12V and 42V. The physical structure of the multi-voltage vehicle electrical distribution system is first described below in order then to explain its mode of operation with the aid of Figure 3.

The electrical energy is generated in the multi-voltage vehicle electrical distribution system by an integrated starter generator ISG driven by the crankshaft of an

internal combustion engine.

The integrated starter generator ISG is connected on the output side to an electrical converter 1 that generates a dc voltage of 42V, with the output of said converter 1 being connected for the purpose of smoothing said dc voltage to ground via a dc link capacitor C1.

The output of the converter 1 is connected via a switching element S1 to a 36V battery 2 which is thus charged when the switching element S1 is closed.

The output of the converter 1 is furthermore connected via a dc-dc converter 3 to a 12V battery 4, with said dc-dc converter 3 converting the system voltage of 42V made available at the output of the converter 1 to a voltage of 14V. The 12V battery 4 is thus charged via the dc-dc converter 3 while the internal combustion engine is in operation.

The multi-voltage vehicle electrical distribution system furthermore has as an electrical energy store a double-layer capacitor 5 that can be connected via a switching element S2 to the integrated starter generator ISG and which will enable reliable starting of the internal combustion engine after the vehicle has been idle for a longer period. In this exemplary embodiment the double-layer capacitor 5 consists for the purpose of simplification of only four capacitors C2-C5 connected in series. In a 42V vehicle electrical distribution system it is, however, customary for 24 capacitors each having a maximum voltage of 2.3V to be connected in series, giving a total voltage of 55.2V. Said total voltage on the one hand enables reliable provisioning of the system voltage of 42V and, on the other hand, is

below the limit of 60V up to which no special insulation measures are required for electrical systems.

The multi-voltage vehicle electrical distribution system furthermore has a conventional charge-equalizing circuit 6 that effects charge equalizing between the individual capacitors C2-C5 of the double-layer capacitor 5. The charge-equalizing circuit 6 has a primary circuit connected via a switching element S3 to ground and via a switching element S4 to the positive terminal of the double-layer capacitor 5, with a primary winding L1 being located in said primary circuit. The charge-equalizing circuit 6 furthermore has four secondary circuits each connected in parallel with the individual capacitors C2-C5. In each case one diode D1-D4 and in each case one secondary winding L2-L5 are connected in series in each secondary circuit. As the functioning of the charge-equalizing circuit 6 is described in detail in EP 0 432 639 A2, a detailed description of how said charge-equalizing circuit 6 operates can be dispensed with below.

The charge-equalizing circuit 6 can be connected via a switching element S5 to the 12V battery 4 and via a further switching element S6 to the 36V battery 2. These connections enable the double-layer capacitor 5 to be recharged via the 12V battery 4 or via the 36V battery 2, as will be described in detail.

The switching elements S3-S6 are driven by a control unit 7 shown greatly simplified in Figure 2.

The control unit 7 has a logic unit 8 which, via a level converter 9, registers the voltage at terminal 15 of the motor vehicle electrical distribution system as well as the

switch position of the switching element S2 in order to drive the switching elements S1 and S3-S6 as a function thereof, as will be described in detail.

The control unit 7 furthermore has a comparator unit 10 which measures the battery voltage U_{BAT12} at the output of the 12V battery 4 and compares said voltage with a predefined minimum value $U_{BAT12,MIN}$. If said minimum value $U_{BAT12,MIN}$ has been exceeded, the comparator unit 10 will pass on a High level to the logic unit 8, with said High level indicating a sufficient charging level of the 12V battery 4.

The control unit 7 furthermore has a comparator unit 11 which measures the battery voltage U_{BAT36} at the output of the 36V battery 2 and compares said voltage with a predefined minimum value $U_{BAT36,MIN}$. If said minimum value $U_{BAT36,MIN}$ has been exceeded, the comparator unit 11 will pass on a High level to the logic unit 8, with said High level indicating a sufficient charging level of the 36V battery 2.

A comparator unit 12 is furthermore provided which registers the voltage U_C of the double-layer capacitor 5 and compares said voltage with a predefined minimum value $U_{C,MIN}$. If said minimum value $U_{C,MIN}$ has not been reached, the comparator unit 12 will then pass on a High level to the logic unit 8 to indicate that the double-layer capacitor 5 needs to be recharged.

The control unit 7 furthermore has a comparator unit 13 which compares the voltage U_C of the double-layer capacitor 5 with a predefined maximum value $U_{C,MAX}$. If said maximum value has been exceeded, the comparator unit 13 will pass on a High level to the logic unit logic unit 8, with said High level indicating that the process of charging the double-

layer capacitor 5 should be terminated.

Finally, the control unit has a timer 14 which daily issues a trigger signal to the logic unit 8 to prompt the execution of the operating method according to the invention.

The control unit 7 detects travel operation from application at terminal 15 of the system voltage of 14V. In this operating state the switches S1 or S2 as well as S4 are closed, whereas the switches S5 and S6 are open. So the charge-equalizing circuit 6 is then electrically connected via the switching element S4 to the double-layer capacitor 5 but is split from the 12V battery 4 and from the 36V battery 2. Charge equalizing between the individual capacitors C2-C5 of the double-layer capacitor 5 can then take place by way of pulsating driving of the switching element S3. Charging of the double-layer capacitor 5 as a whole will, however, not then be possible owing to the open switching elements S5 and S6, the charge-equalizing circuit 6 being split from the 12V battery 4 and from the 36V battery 2.

It must, however, be said that charge equalizing between the individual capacitors C2-C5 of the double-layer capacitor 5 should not take place when the double-layer capacitor 5 is connected to the integrated starter generator ISG and is being subjected to a high dynamic load. The control unit 7 therefore also evaluates the switching status of the switching element S2 and will block the switching element S3 of the charge-equalizing circuit 6 when the switching element S2 is closed.

The switching elements S1, S2, and S4 are, by contrast, open while the vehicle is idle so that the double-layer capacitor 5 is electrically split from the charge-equalizing circuit

6. Said splitting will enable recharging of the double-layer capacitor 5 as the charging voltage is not limited by the capacitor voltage U_C.

The operating method shown in Figure 3 will be carried out here in order to retain the charge stored in the double-layer capacitor 5 and thereby enable reliable starting of the internal combustion engine.

The timer 14 is first reset at the beginning of the operating method according to the invention, then incremented in a loop until a predefined period of time T_{MAX} has elapsed, with said period of time T_{MAX} corresponding to, for example, one day.

The voltage U_C will then be measured at the positive terminal of the double-layer capacitor 5 to be able to check whether the double-layer capacitor 5 needs to be recharged.

The measured voltage U_C is therefore compared with a minimum value $U_{C,MIN}$, with the operating method being terminated if the voltage U_C exceeds said minimum value $U_{C,MIN}$, the double-layer capacitor 5 not then needing to be recharged.

If, by contrast, the voltage U_C of the double-layer capacitor 5 has fallen below the minimum value $U_{C,MIN}$ owing to self-discharging of the double-layer capacitor 5, then said double-layer capacitor 5 will need to be recharged to ensure reliable restarting of the internal combustion engine.

A check is then carried out in the next steps to determine whether the charging level of the 36V battery 2 or of the 12V battery 4 will suffice to recharge the double-layer capacitor 5.

For this purpose, the voltage U_{BAT36} of the 36V battery 2 is first measured and compared with a minimum value $U_{BAT36,MIN}$.

If the voltage U_{BAT36} of the 36V battery 2 exceeds the predefined minimum value $U_{BAT36,MIN}$, then the energy for recharging the double-layer capacitor 5 can be taken from said 36V battery 2. In this case the switching element S6 will be closed in order to connect the charge-equalizing circuit 6 to the 36V battery 2, whereas the switching element S5 will remain open.

If, by contrast, the voltage U_{BAT36} of the 36V battery 2 is below the predefined minimum value $U_{BAT36,MIN}$, then the double-layer capacitor 5 ought not to be recharged from the 36V battery 2, its charging level being insufficient for this. That will prevent the 36V battery from being damaged.

The voltage U_{BAT12} of the 12V battery 4 is then measured in a next step in order to check whether the electrical energy for recharging the double-layer capacitor 5 can be taken from the 12V battery.

The measured voltage U_{BAT12} of the 12V battery is therefore compared with a predefined minimum value $U_{BAT12,MIN}$.

If the voltage U_{BAT12} of the 12V battery 4 is below the predefined minimum value $U_{BAT12,MIN}$, then the double-layer capacitor 5 ought not to be recharged from the 12V battery 4, its charging level being insufficient for this. In this case the double-layer capacitor 5 will not be recharged and the operating method according to the invention will be terminated.

If, by contrast, the voltage U_{BAT12} of the 12V battery 4 exceeds the predefined minimum value $U_{BAT12,MIN}$, then the energy for recharging the double-layer capacitor 5 can be taken from said 12V battery 4. In this case the switching element S5 will be closed in order to connect the charge-equalizing circuit 6 to the 12V battery 4, whereas the switching element S6 will be opened.

Pulsating driving of the switching element S3 will then take place in the case both of recharging from the 12V battery 4 and recharging from the 36V battery 2 in order to charge the double-layer capacitor 5.

While the double-layer capacitor 5 is being charged, the voltage U_C of the double-layer capacitor 5 will be continuously measured and compared with a maximum value $U_{C,MAX}$ to avoid excessive recharging of the double-layer capacitor 5.

The process of charging will therefore be interrupted if the voltage U_C of the double-layer capacitor 5 exceeds the predefined maximum value $U_{C,MAX}$. The two switch elements S5 and S6 as well as the switching element S3 will be opened for this purpose.

The timer 14 will then be reset again and the procedural steps described above will be executed anew in a loop.

In conclusion, Figure 4 shows what is termed a transfer gate 15 that can be used for implementing the switching elements S1-S6 in circuit engineering terms. The transfer gate 15 essentially consists of two series-connected MOSFET transistors T1 and T2 having two parasitic diodes D5 and D6 and of a resistor R1. Both MOSFET transistors T1 and T2 are

turned on when a positive voltage of approximately U_{GS} = +10V is applied between the gate and source of the transfer gate 15, and said transfer gate 15 is activated. If, by contrast, the gate-source voltage U_{GS} is 0V, the transfer gate 15 is deactivated. In each case only one of the two MOSFET transistors T1, T2 is turned off in the deactivated state since the respective other MOSFET transistor T1 or, as the case may be, T2 is operated with reverse polarity and its parasitic diode D5 or, as the case may be, D6 is conducting.